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Agricultural Memorandum No 874

SITING OF SHELTER FOR GLASSHOUSES

1. INTRODUCTION

Heat loss from glasshouses is related to temperature lift and wind speed. Permeable shelter can reduce wind speed and therefore fuel use. If all round shelter is provided then a 20% reduction in wind speed is possible with a corresponding reduction in fuel use of around 10%. In general this is impractical and advice to growers on where to site shelter is usually based on an analysis of wind direction (wind-rose). Moderate winds being the most frequent, cause the greatest loss and it is usually assumed that this occurs with the prevailing wind(s). This memorandum investigates the hypothesis that frequency of wind direction can be used as a predictor of heat loss for winds of a given direction.

2. ANALYSIS OF DATA

The loss of heat from a glasshouse by transmission is given by:-

$H = U \times L$ where H = the heat loss
U = the transmission factor
L = the temperature lift (outside - inside)

For glasshouses in reasonably good condition - Morris showed that:-

$U = 0.75 + 0.05\ W$ BTU/sq ft/hour/$^{\circ}$F where W is the 10m wind speed in mph

Converting this formula for metric units and wind speeds in kts gives:-

$U = 4.25 + 0.326\ W$ Watts/m^2/$^{\circ}$C

Frequency analyses of temperature against wind direction for different wind speeds were obtained for both night and day for Oct-March 1957-1978 for Boscombe Down and Exeter. Class intervals were: temperature (2°C), direction (30 degrees) and speed (5 kts). Winds above 30 kts were assumed to have a mean speed of 33 kts. Total heat losses for calm conditions and for each sector were CALCULATED using the above formula and assuming Tomato Blue Print base temperatures ie 16°C at night and 20°C during the day. Transmission factors (U values) are given in Appendix 1. Total losses for the 22 year period for both stations are summarised in Tables 1 and 2.

The numbers of occasions when the wind blew from each sector were expressed as a percentage of the total number of observations (excluding calms). Heat loss for each sector was ESTIMATED by apportioning the total loss (for all sectors, excluding calms) according to the percentage of winds from that sector. The wind frequencies, estimated heat losses and errors in the estimates are shown in Tables 3 and 4.

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It was thought that it may be possible to obtain better estimates of heat losses for the sectors by apportioning the total loss according to the frequency distribution of some limited range of wind speeds such as 6 to 15 kt, which contribute most to the total heat loss (see Appendix II). But although several ranges were tried none produced better results than the method described. When calm conditions were excluded from both estimated and calculated heat losses then correlation coefficients between the two were 0.846 for Boscombe and 0.769 for Exeter. With 10 degrees of freedom both are significant at the 1% level. Figures 1 and 2 show calculated and estimated losses. Appendix II shows the effect of a 20% reduction in wind speed on fuel use. All data are for 22 year totals unless otherwise stated.

3. DISCUSSION

Figures 1 and 2 show that estimates of heat losses for each sector based on the frequency distribution of wind directions show the same general pattern as losses calculated from detailed wind direction/wind speed/temperature data. However they underestimate heat losses from winds with a NNE'ly component and overestimate losses from winds with a SSW'ly component. The error distributions are similar for both stations and are non-random. For Boscombe Down an underestimate of 135 kWh/m^2 for 060° winds and an overestimate of 133 kWh/m^2 occurs with winds from the 240° sector, these correspond to absolute errors of - 21% and + 19%. For Exeter the largest errors are for 060° and 180° winds, being - 176 kWh/m^2 and + 192 kWh/m^2 respectively, corresponding to absolute errors of - 23% and + 32%.

4. CONCLUSIONS

Total heat loss can be calculated from a wind speed/temperature analysis and apportioned to sectors using a frequency of direction analysis. The errors involved (over 30%) would be too great for a quantative use of the results. However advice on where to site shelter based on the traditional method of using wind roses for a subjective assessment would not give significantly different results than if full heat loss data were available. It is assumed that a meteorologist would bias his estimates of heat loss toward the colder north-easterly sectors. Both Figures 1 and 2 show the danger of assuming protection from the SW quarter is most effective. Fuel savings could be offset by light loss but this would be of less effect with shelter in the NE quarter than in the SW. The two stations considered in this memorandum are in the South West and it is expected that the errors would be greater for stations in Eastern England.

Appendix II shows that a calculated fuel saving of about 8% could be achieved for Boscombe Down and Exeter if all round shelter gave a 20% reduction in wind speed.

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REFERENCES

Morris L G (1961) - The Heating and Ventilation of Greenhouses - "Atti Del Convegne Internazionale per Laddifesa Delle Colture O Degli Allevament Dalle Avversita Atmosferische - Torino 22-23 Ottobre 1961".

CALCULATED SECTOR HEAT LOSSES (kWh/m^2) OCT-MARCH 1/1/57-31/12/78
DERIVED FROM FREQUENCY ANALYSIS OF TEMPERATURE Vs WIND DIRECTION

TABLE 1. BOSCOMBE DOWN - (From hourly data)

	WIND DIRECTION													
	360	030	060	090	120	150	180	210	240	270	300	330	CALM	TOTAL
Night	291	262	335	497	288	251	347	394	391	418	480	317	241	4512
Day	269	241	314	386	234	227	327	343	327	389	427	274	112	3870
Total	560	503	649	883	522	478	674	737	718	807	907	591	353	8382
% excluding calm	7.0	6.3	8.1	11.0	6.5	5.9	8.4	9.2	8.9	10.0	11.3	7.4		100.0

TABLE 2. EXETER - (From 3 hourly data)

	WIND DIRECTION													
	360	030	060	090	120	150	180	210	240	270	300	330	CALM	TOTAL
Night	212	400	394	150	186	267	303	220	179	245	383	232	426	3597
Day	229	371	358	124	205	292	288	213	169	295	500	258	185	3487
Total	441	771	752	274	391	559	591	433	348	540	883	490	611	7084
% excluding calm	6.8	11.9	11.6	4.2	6.0	8.6	9.1	6.7	5.4	8.4	13.7	7.6		100.0

NUMBER OF OBSERVATIONS OF WIND FROM EACH SECTOR AND ESTIMATED HEAT LOSSES OCT-MAR 1/1/57-31/12/78
BASED ON FREQUENCY ANALYSIS OF WIND DIRECTION

TABLE 3. BOSCOMBE DOWN - (From hourly data)

	WIND DIRECTION													
	360	030	060	090	120	150	180	210	240	270	300	330	CALM	TOTAL
Night	3131	2766	3324	5261	3511	3411	5001	5801	5773	5602	5863	3489	4429	57362
Day	2425	2077	2481	3331	2357	2480	3519	3797	3766	4182	4200	2565	1674	38854
Total	5556	4843	5805	8592	5868	5891	8520	9598	9539	9784	10063	6054	6103	96216
% frequency excluding calm	6.1	5.4	6.4	9.5	6.5	6.5	9.5	10.7	10.6	10.9	11.2	6.7		100.0
Estimated Heat loss (kWh/m^2)	490	433	514	763	522	522	763	859	851	875	899	538		8029
Error	- 70	- 70	- 135	- 120	0	44	89	122	133	68	- 8	- 53		
% error	- 13	- 14	- 21	- 16	0	9	13	17	19	8	- 1	- 9		

TABLE 4. EXETER - (From 3 hourly data)

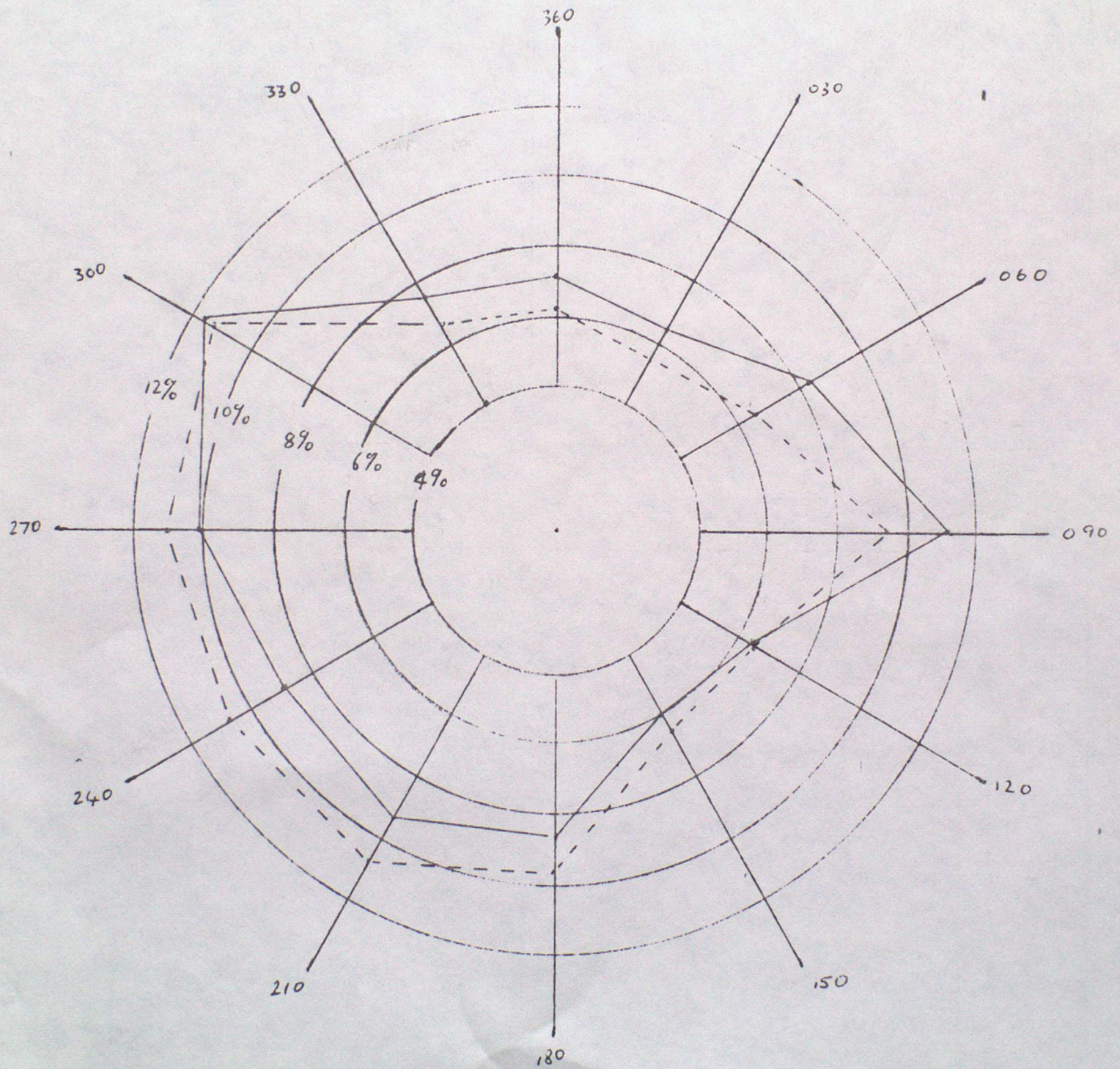
	WIND DIRECTION													
	360	030	060	090	120	150	180	210	240	270	300	330	CALM	TOTAL
Night	960	1556	1523	702	1035	1818	2135	1566	1114	1331	1806	1058	2759	19363
Day	714	1047	1003	397	750	1228	1285	986	739	1086	1670	850	954	12709
Total	1674	2603	2526	1099	1785	3046	3420	2552	1853	2417	3476	1908	3713	32072
% frequency excluding calm	5.9	9.2	8.9	3.9	6.3	10.7	12.1	9.0	6.5	8.5	12.3	6.7		100.0
Estimated Heat loss (kWh/m^2)	382	595	576	252	408	693	783	583	421	550	796	434		6473
Error	- 59	- 176	- 176	- 22	17	134	192	150	73	10	- 87	- 56		
% error	- 13	- 23	- 23	- 8	4	24	32	35	14	1	- 18	- 9		

FIGURE 1

Boscombe Down Oct-March 1957/78

Percentage heat loss for winds excluding calm

(Each point represents a 30° sector)



——— CALCULATED

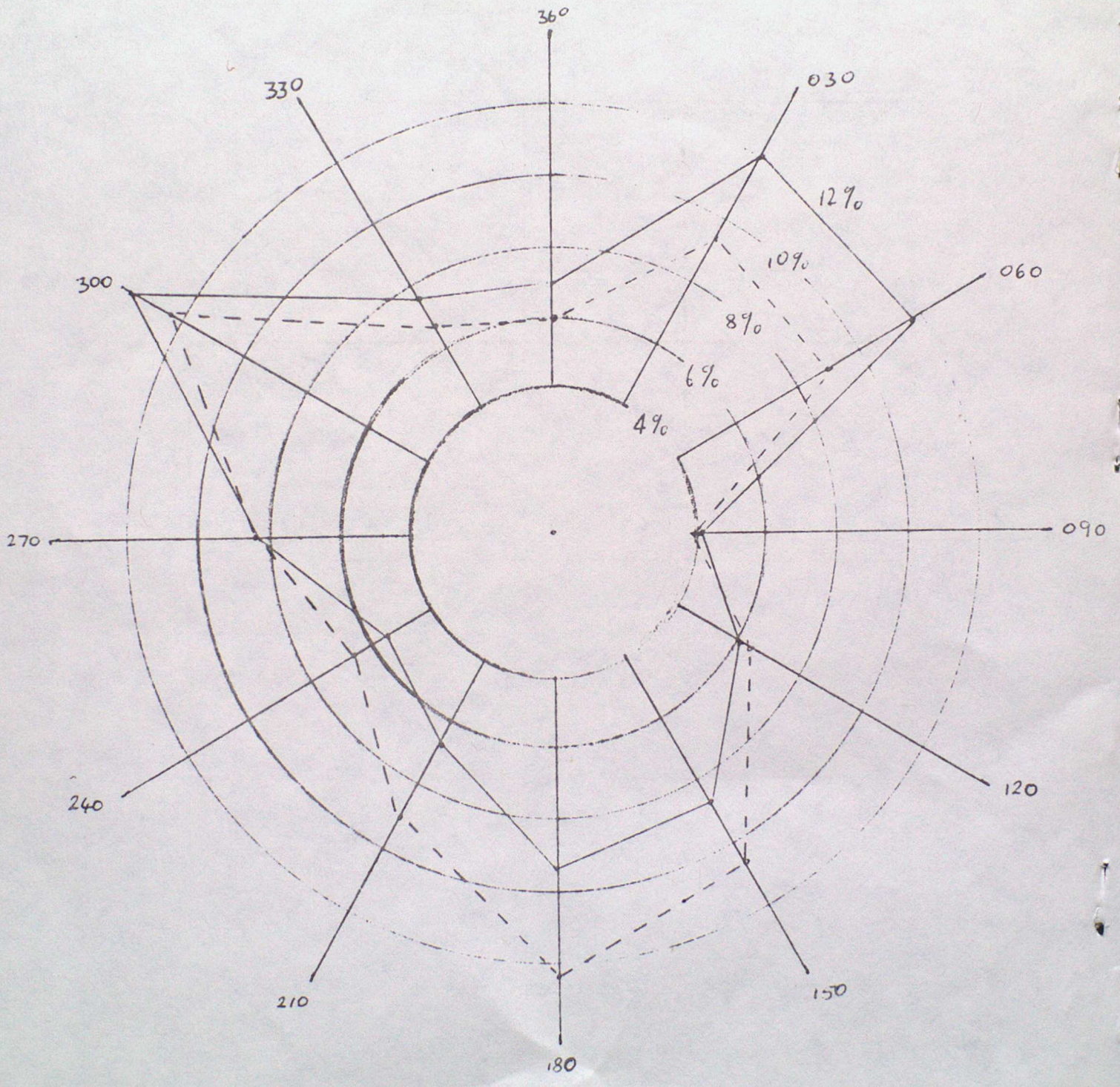
- - - - - - ESTIMATED

FIGURE 2

Exeter Oct-March 1957/78

Percentage heat loss for winds excluding calm

(Each point represents a 30° sector)



APPENDIX I

TRANSMISSION FACTORS (Watts/m^2/^oC)

Windspeed KTS	Unprotected Site	Assuming 20% Reduction
0	4.250	4.250
3	5.228	5.032
8	6.858	6.336
13	8.488	7.640
18	10.118	8.944
23	11.748	10.248
28	13.378	11.552
33	15.008	12.856

APPENDIX II

CALCULATED HEAT LOSSES (kWh/m^2) OCT-MARCH 1957/78

Windspeed KTS	BOSCOMBE DOWN				EXETER			
	Night	Day	Total	With 20% reduction in windspeed	Night	Day	Total	With 20% reduction in windspeed
0	241	112	353	353	426	185	611	611
1- 5	704	433	1137	1094	719	469	1188	1143
6-10	1597	1099	2696	2491	928	750	1678	1549
11-15	1216	1221	2437	2194	806	1011	1817	1634
16-20	494	647	1141	1009	371	570	941	832
21-25	194	264	458	401	240	335	575	502
26-30	56	69	125	108	71	111	182	157
> 30	13	22	35	30	39	53	92	79
TOTALS	4515	3867	8382	7680	3600	3484	7084	6507
	Saving = 8.4%				Saving = 8.1%			